MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

EME2146 – APPLIED THERMODYNAMICS
(ME)

20 OCTOBER 2018
02.30 p.m. - 04.30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of six pages (including the cover page) with four questions and an Appendix.
2. Answer ALL four questions.
3. Each question carries 25 marks and the distribution of the marks for each question is given in brackets [ ].
4. Write all your answers in the answer booklet provided.
5. Property-tables booklet is provided for your reference.

Question 1

In a rigid container, 116 g of Butane gas (C_4H_{10}) is well mixed with 100 % excess air (dry air) at 25 °C and 100 kPa initially. The mixture is combusted completely after an ignition. The product gases reach 1000 K at the end of the combustion process. Assume ideal gas for the mixtures of products and reactants where the universal gas constant, R = 8.314 J/mol·K.

Substance	N_2	O_2	CO_2	H_2O	C_4H_{10}
Molecular weight (kg/kmol)	28	32	44	18	58

The dry air composition: nitrogen to oxygen ratio by mole = 3.76.

a. Write the stoichiometric combustion equation.

[3 marks]

b. Write the combustion equation with 100% excess air.

[3 marks]

c. Calculate the air-fuel ratio.

[3 marks]

d. Find the enthalpy of formation for C_4H_{10}, CO_2, and H_2O at 298 K and 100 kPa from the property table.

[3 marks]

e. Determine the heat transfer from the container in kJ.

[9 marks]

f. Calculate the volume of the container in m^3.

[2 marks]

g. Calculate the pressure in the container after combustion in kPa.

[2 marks]

Continued...

Question 2

An air conditioning system uses R-134a as the refrigerant, operating in a refrigeration cycle. The refrigerant enters the compressor as superheated vapor at 200 kPa and 0 °C and leaves the condenser at 1200 kPa and 40 °C. The energy consumption of the compressor is 1.5 kW and the compression process (state 1 $\longrightarrow$ 2) is considered isentropic. Pressure in the condenser (state 2 $\longrightarrow$ 3) and evaporator (state 4 $\longrightarrow$ 1) are maintained constant. The expansion valve (state 3 $\longrightarrow$ 4) is well insulated.

a. Sketch and label the $T - s$ diagram of the cycle.

[2 marks]

b. Sketch and label the $p - h$ diagram of the cycle.

[2 marks]

c. Find enthalpies at state 1, 2, 3 and 4 in kJ/kg.

[6 marks]

d. Calculate the mass flow rate of the refrigerant in kg/s.

[3 marks]

e. Calculate the rate of heat transfer at the evaporator in kW.

[3 marks]

f. Calculate the rate of heat transfer at the condenser in kW.

[3 marks]

g. Determine the coefficient of performance of the cycle.

[3 marks]

h. If the air conditioning unit is switched into heat pump, what is the coefficient of performance?

[3 marks]

Continued...

Question 3

A piston-cylinder contains 5 g of a gaseous substance. Piston compression speed is controlled so that 2.00 kJ of heat is allowed to transfer through the wall and the temperature is maintained constant throughout the compression process, $T_i = 400$ K. Piston compressed from its initial volume, $V_i = 1$ liter, to the final volume, $V_e = 0.1$ liter, as shown in Figure Q3. The surrounding temperature, $T_0 = 300$ K. Assume ideal gas where the gas constant and specific heat ratio of the substance are $R = 0.3$ kJ/kg·K and $\gamma = 1.4$ respectively.

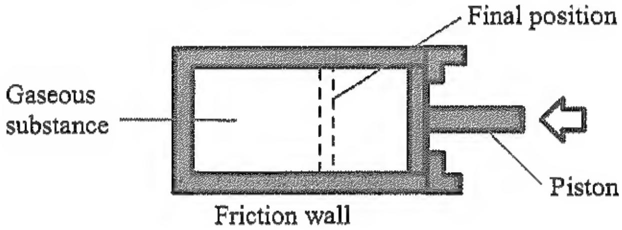

Figure Q3

a. Find the constant volume and constant pressure specific heat.

[2 marks]

b. Find the initial pressure of the cylinder.

[2 marks]

c. Calculate the change of entropy of the process in J/K.

[2 marks]

d. Calculate the internal entropy generation of the process in J/K.

[2 marks]

e. Calculate the reversible work input (frictionless piston) in kJ.

[3 marks]

f. Calculate the irreversibility of the process in kJ.

[2 marks]

g. If the compression process is carried out and maintained at the surrounding temperature, $T_0 = 300$ K, determine the integral $\int_{V_e}^{V_i} pdV$. Hence determine the irreversibility of the process.

[8 marks]

h. Sketch the $p - v$ diagram for both compression processes at T_0 and T_{out}. In the graph, highlight the irreversibility of process in part (g).

[4 marks]

Continued...

Question 4

A rigid vessel contains 1 kg of a gaseous pure substance. The equation of state of the substance is expressed by relating the compressibility factor, Z, to the reduced temperature, T_r and dimensionless volume, v_r':

$$Z = 1 + \frac{C_1 - C_2/T_r}{v_r'} \; ; \; v_r' = \frac{v}{RT_c/p_c}$$

where $C_1 = 0.1$ and $C_2 = 0.25$ are empirical constant. The critical pressure, p_c and critical temperature, T_c of the substance are 5.00 MPa and 150 K respectively. Initially, the vessel is held at $T_1 = 375$ K and $p_1 = 1$ MPa. Heat is added into the vessel and temperature increases and finally stable at $T_2 = 750$ K. Under the particular range of pressure and temperature, the gas constant and the constant pressure specific heat of the substance can be taken are $R = 0.26$ kJ/kg·K and $c_p = 0.92$ kJ/kg·K respectively.

a. Find the reduced temperature at initial and final state and reduced pressure at initial state.

[3 marks]

b. Determine the volume of the vessel.

[7 marks]

c. Calculate the pressure at final state.

[3 marks]

d. Determine the enthalpy departure, $(u^* - u)$, from the ideal gas value at initial and final state.

[8 marks]

e. Using the enthalpy departure values in part (d), calculate the amount of heat transferred.

[4 marks]

Continued...

APPENDIX

A1. Clayperon Relation:

$$\frac{dp_{sat}}{dT} = \frac{s_{fg}}{v_{fg}} = \frac{h_{fg}}{Tv_{fg}}$$

A2. Maxwell Relations:

$$\left(\frac{\partial T}{\partial v}\right)_s = -\left(\frac{\partial p}{\partial s}\right)_v; \quad \left(\frac{\partial T}{\partial p}\right)_s = \left(\frac{\partial v}{\partial s}\right)_p$$
$$\left(\frac{\partial v}{\partial T}\right)_p = -\left(\frac{\partial s}{\partial p}\right)_T; \quad \left(\frac{\partial p}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T$$

A3. Change of internal energy, enthalpy, and entropy:

$$u_2 - u_1 = \int_{T_1}^{T_2} c_v dT + \int_{v_1}^{v_2} \left[T\left(\frac{\partial p}{\partial T}\right)_v - p\right] dv$$
$$h_2 - h_1 = \int_{T_1}^{T_2} c_p dT + \int_{p_1}^{p_2} \left[v - T\left(\frac{\partial v}{\partial T}\right)_p\right] dp$$
$$s_2 - s_1 = \int_{T_1}^{T_2} \frac{c_v}{T} dT + \int_{v_1}^{v_2} \left(\frac{\partial p}{\partial T}\right)_v dv = \int_{T_1}^{T_2} \frac{c_p}{T} dT - \int_{p_1}^{p_2} \left(\frac{\partial v}{\partial T}\right)_p dp$$

A4. Enthalpy, entropy and internal energy of departure:

$$\frac{(h^* - h)_T}{RT_c} = \int_0^{p_r} \left[T_r^{\,2}\left(\frac{\partial Z}{\partial T_r}\right)_p\right] \frac{dp_r}{p_r}$$
$$\frac{(s^* - s)_T}{R} = \int_0^{p_r} \left[Z - 1 + T_r\left(\frac{\partial Z}{\partial T_r}\right)_p\right] \frac{dp_r}{p_r}$$
$$\frac{(u^* - u)_T}{RT_c} = \frac{(h^* - h)_T}{RT_c} + T_r(Z - 1)$$

A5. Specific heats difference:

$$c_p - c_v = \frac{Tv{\alpha_p}^2}{\beta_T}$$
$$c_p - c_v = R \text{ (for ideal gas)}$$

A6. Some useful calculus relations:

Integration by parts: $\int \spadesuit(\blacklozenge)\clubsuit(\blacklozenge)\, d\blacklozenge = \spadesuit(\blacklozenge) \int \clubsuit(\blacklozenge)\, d\blacklozenge - \int \left[\left(\int \clubsuit(\blacklozenge)\, d\blacklozenge\right)\spadesuit'(\blacklozenge)\right] d\blacklozenge$

Integration of quotient: $\int \frac{\clubsuit'(\blacklozenge)}{\clubsuit(\blacklozenge)} d\blacklozenge = \ln[\clubsuit(\blacklozenge)]$

Differentiation of product $(\spadesuit(\blacklozenge)\clubsuit(\blacklozenge))' = \spadesuit'(\blacklozenge)\clubsuit(\blacklozenge) + \spadesuit(\blacklozenge)\clubsuit'(\blacklozenge)$

Differentiation of quotient: $\left(\frac{\spadesuit(\blacklozenge)}{\clubsuit(\blacklozenge)}\right)' = \frac{\spadesuit'(\blacklozenge)\clubsuit(\blacklozenge) - \spadesuit(\blacklozenge)\clubsuit'(\blacklozenge)}{[\clubsuit(\blacklozenge)]^2}$

Cyclic relation: $\left(\frac{\partial \spadesuit}{\partial \clubsuit}\right)_{\blacklozenge} \left(\frac{\partial \clubsuit}{\partial \blacklozenge}\right)_{\spadesuit} \left(\frac{\partial \blacklozenge}{\partial \spadesuit}\right)_{\clubsuit} = -1$

End of Paper